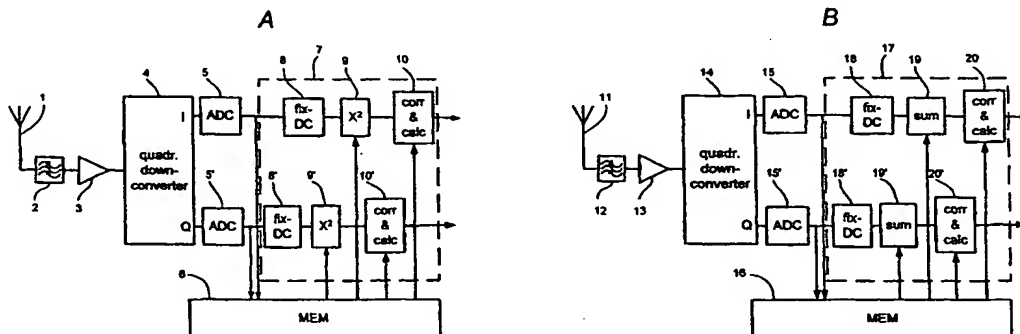




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## (54) Title: A HOMODYNE RADIO RECEIVER



## (57) Abstract

A homodyne radio receiver apparatus receives radio frequency signal bursts containing a number of symbols and generates digital samples of at least a complex base band signal (I and Q) of each signal bursts. A DC compensator comprises an average calculator (8, 8'), which determines an average DC-level of said samples, and a signed square sum calculator (9, 9'), which calculates a signed square sum of a plurality of said samples and weights the square sum by a compensation factor. Correction means (10, 10') subtracts the square sum from an output of said average calculator means for forming the DC-level estimate.

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## TITLE: A HOMODYNE RADIO RECEIVER

5           **Field of the Invention**

The present invention relates generally to a homodyne radio receiver apparatus and more particularly to a homodyne radio receiver apparatus, comprising DC compensation means for determining a DC-level estimate of a received signal burst.

**Description of the Prior Art**

Homodyne receivers are well known for use in wireless telecommunication devices, such as mobile telephones.

15           Generally, a homodyne receiver comprises dual communication channels, which are commonly known as I and Q channels. The dual-channel homodyne receiver is used in prior art digital mobile telephones, such as GSM phones.

The receiver comprises an antenna for receiving an incoming electromagnetic communication signal, such as a TDMA signal ("Time Division Multiple Access") representing a stream of digital data symbols, which have been modulated onto two orthogonal carrier waves. The received signal is fed through a bandpass filter, amplified in an amplifier and then split into two identical signals. The first of these signals goes to a first signal path, where it is initially mixed in a mixer with an intermediate frequency signal. The intermediate frequency signal is fed from a local oscillator and passes unmodified through a phase shifter. Similarly, the second signal goes to a second signal path, where it is mixed in a mixer with the intermediate frequency signal from the local oscillator, once the phase of the intermediate frequency signal has been shifted by 90° in the phase shifter.

35           The output of the mixer is filtered by a lowpass filter and amplified in a second amplifier. Subsequently, the signal is fed to an analog-to-digital converter for

sampling the signal and converting it to a digital signal comprising the stream of data symbols. The digital signal is filtered in a digital lowpass filter, and the digital data symbols contained in the signal are supplied to a digital memory. An estimated DC-level of the signal is determined and subtracted from the digital signal forming a DC-level compensated digital signal, which is demodulated.

The stream of digital data symbols are subsequently used by other components in the mobile telephone for producing e.g. an audible output through a loudspeaker.

However, it has been found that prior art homodyne radio receivers have insufficient receiver performance, particularly for representing data messages sent between two computers during a data communication session.

The information bandwidth of a homodyne receiver goes down to DC in frequency, but the DC-level contains no information. Hence, the DC-level needs to be removed before the information can be demodulated properly.

The DC-level of a signal can be estimated in different ways. One way of estimating the DC-level is disclosed in US-A-5 838 735, wherein the DC-level of a signal is determined by means of an average calculator, which calculates the mean value or the average DC-level of the digital signal according to the following expression:

$$DC \text{ level} = \frac{1}{N} \sum_{i=1}^N S(i)$$

Hence, the mean value of the samples  $S(i)$  is determined by forming the average of a predetermined number  $N$  of the most recently received samples. Then, the average DC-level is subtracted from the digital signal forming a DC-level compensated digital signal.

In TDMA systems like GSM it is difficult to determine the DC-level, because the time to measure the DC-level is

limited to one received burst, since the next received burst can have another DC-level due to for instance frequency hopping. The number of samples included in an average calculation is for example 128bits. This implies  
5 the assumption that, the average of 128 GMSK (Gaussian Minimum Shift Keying) modulated I samples (or Q samples) is zero. However, averages equal to zero is only the case when signal points are positioned equally frequent in all quadrants in the IQ plane.

10 An investigation shows that the modulation in some cases causes a DC offset of more than 20% (typically 10%) of the amplitude for 128 samples. Such, DC-level estimates causes a limited performance for high C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio)  
15 signals, and an unsatisfying number of bit errors, particularly when the signals are used for transmitting data during a data communication session. Of course, the accuracy in the DC-level estimate is also dependent on the modulation type.

#### 20 Summary of the Invention

An object of the present invention is to provide a homodyne radio receiver apparatus and method, providing an improved DC-level estimate and compensation.

25 This object is achieved by a homodyne radio receiver apparatus according to the invention, wherein a radio frequency signal burst of a number of symbols is received in the apparatus and converted to digital samples for DC compensation by a DC compensator. A first estimate of the  
30 DC-level is determined by calculating an average DC-level of the samples in an average calculator.

Then, according to one aspect of the invention, a signed square sum of a plurality of the samples are calculated by a signed square sum calculator in the DC  
35 compensator. The square sum is weighted by a compensation

factor, and correction means connected to the square sum calculator subtracts the weighted square sum from the average DC-level for forming an improved DC-level estimate.

According to another aspect of the invention, the DC compensation means comprises a signed sum calculator for calculating a signed sum of a plurality of the samples and weighting the sum by a compensation factor. Correction means is also included in the DC compensation means, wherein an output of the signed sum calculator means is subtracted from an output of the average calculator means for forming the DC-level estimate.

An introduction of a DC compensator, which estimates a DC-level as described and compensates the signal with a parameter dependent on the signal shape, the output from the function will become correlated with the error in the DC-level estimate. The function extracts information from the signal, which can be used to compensate for any error in the DC-level estimate.

An advantage of the present invention is that the DC-level estimate and compensation according to the invention removes the limiting DC-level error for high C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio) signal conditions, by considering information characteristics of the signal for DC-level estimation, resulting in a reduced number of bit errors for the current signal conditions.

#### **Brief Description of the Drawings**

In order to explain the invention in more detail and the advantages and features of the invention references in the following detailed description of the preferred embodiment are made to the accompanying drawings, in which

FIG 1A is a block diagram of a first embodiment of a homodyne receiver according to the invention,

FIG 1B is a block diagram of a second embodiment of a homodyne receiver according to the invention,

FIG 2 shows the integrated area of the DC-error probability function between -5 to +5% as a function of the slope in the compensation equation,

FIG 3 shows the integrated area of the DC-error probability function between -5 to +5% as a function of the slope in the compensation equation,

FIG 4 is a plot of the correlation for  $C/I > 100$  dB,

FIG 5 is a plot of the correlation for  $C/I=6$ dB,

FIG 6 is a plot of the probability functions for the DC error with and without compensations for  $C/I>100$ dB,

FIG 7 shows the compensated probability function for different  $C/I$ ,

FIG 8 shows the compensated probability function for different  $C/I$ ,

FIG 9 is a plot of the correlation coefficient versus the counter limit,

FIG 10 shows the DC estimate error as a function of the difference between the number of negative and positive samples,

FIG 11 shows -5% to +5% error estimate vs. the compensation slope, and

FIG 12 is a plot of the probability function for the DC error with and without compensation.

#### Detailed Description of the Invention

One embodiment of a homodyne radio receiver apparatus according to the invention, which estimates a DC-level of received radio frequency signal bursts and removes the estimated DC-level of each burst before the signal is demodulated, is shown in a schematical block diagram in FIG 1.

A signal burst containing a number of symbols, including a carrier signal modulated by a modulating

signal, is received by an antenna 1 and is filtered by a bandpass filter 2. An amplifier 3 amplifies the filtered signal generated by the filter 2. Further, the amplified signal burst is downconverted to complex base band signals I (in-phase) and Q (quadrature) by a conventional  
5 quadrature down-converter 4. The output I, Q from the down-converter 4 is preferably filtered and amplified by additional filters and amplifiers before the output is sampled and converted to a digital signal by an analog-to-digital converter ADC 5,5'. The digital signal may be  
10 filtered in a digital filter, and the digital data symbols or samples contained in the signal are supplied to a digital memory 6 for later retrieval.

The output from the ADC 5,5' is fed to a DC compensation device 7, which determines a DC-level estimate of  
15 the received signal and subtracts the determined DC-level from the signal burst before it is demodulated. In order to determine the DC-level estimate the DC compensation device is adapted to process the received signal burst in a  
20 plurality of steps according the invention. The output of the ADC 5,5' is fed to an average calculator 8,8', which estimates the average DC-level of a number of samples. Additionally, the average calculator 8,8' determines the peak value of the signal by identifying the maximal sample  
25 value and subtracting the estimated average DC-level from the maximal sample value. The peak value is supplied to the next step of the signal path together with the estimated average DC-level.

The next step in the signal path is a square sum  
30 calculator 9,9'. The samples of the received signal burst stored in the digital memory 6 are read by the square sum calculator 9,9', which standardizes the symbols with reference to the estimated average DC-level and the peak value before a signed square sum of the samples are  
35 calculated and weighted by a compensation factor, described



later. Then, a final DC-level estimate is calculated in the square sum calculator 9,9' by subtracting the weighted calculated signed square sum.

Further, the output of the square sum calculator 9,9' is supplied to a correction and calculator block 10,10', in which an improved DC-level estimate is calculated by subtracting the weighted calculated signed square sum from the estimated average DC-level. Finally, the improved DC-level estimate is subtracted from each sample read from the memory 6. In an alternative embodiment of the invention, the subtraction of the weighted calculated signed square sum from the estimated average DC-level is performed by the square sum calculator 9,9'.

Consequently, the output of the correction and calculator block 10,10' at the end of the signal path will finally provide a first part of the stream of digital data symbols, that were contained in and carried by the analog signal initially received at the antenna 1. The stream of digital data symbols are subsequently used by other components in the mobile telephone for producing e.g. an audible output through a loudspeaker, such as speech. Alternatively, the stream of digital data symbols may represent data messages sent between two computers during a data communication session.

The randomness of the wanted signal, i.e the modulating signal, and the number of symbols used for the estimate, effects the error in the DC-level calculation. For the purpose of illustration, the wanted signal is a randomly GMSK (Gaussian Minimum Shift Keying) modulated signal. The maximum number of symbols to calculate the mean value is set by the burst length.

The above mentioned limits will degrade the performance.

Hence, according to the invention, the error in the DC-level estimate is minimized if the DC-level is compensated with information inherent in the signal burst.

In this embodiment of the invention, the DC-level is estimated according to the following expression (1) for the compensation:

$$DC_{estimate1} = DC_{average} - A \cdot DC_{error1} \quad (1), \text{ wherein}$$

$$DC_{average} = \frac{1}{N} \sum_{i=1}^N S(i) \quad (2), \text{ and}$$

$$DC_{error1} = \frac{1}{N} \cdot \sum_N |x| \cdot x \quad (3)$$

10

Thus, the estimated DC-level,  $DC_{estimate1}$ , is the average DC-level,  $DC_{average}$ , calculated over  $N$  symbols  $S(i)$  compensated by a DC-error,  $DC_{error1}$ , multiplied by a compensation factor  $A$ . The DC-error is estimated by calculating the signed square sum of the signal, wherein  $x = S(i) - DC_{average}$ .

An optimal compensation factor, i.e the relationship between the DC-error and the signed square sum, is determined for different C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio), assuming white noise.

With reference to the graphs in FIG 2, the integrated area of the DC-error probability function between -5 to +5% is shown as a function of the slope, i.e the compensation factor, in the expression (1). The solid line illustrates C/I > 100dB, the dashed line C/I = 20dB, and the dash-dotted line C/I = 12dB, and the dash double dotted line C/I = 6dB.

FIG 3 shows graphs representing the integrated area of the DC-error probability function between -5 to +5% as a function of the slope, i.e the compensation factor, in the expression (1). The solid line illustrates SNR > 100dB, the dashed line SNR = 20dB, the dash-dotted line SNR = 12dB, and the dash double dotted line SNR = 6dB.

According to the graphs in FIG 2 and 3, it is apparent that a value of 2.0 is an optimal slope. Hence, a compensation factor A of -1.0 to -3.0 and preferably -2.0 is an optimal relationship between the DC-error and the signed square sum for a high C/I. Thus, the following expression is an example of a compensation expression used by the DC compensation device 7 for determining a DC-level estimate.

$$10 \quad DC_{estimate} = DC_{average} + 2 \cdot DC_{error} \quad (4)$$

The flatness of the optimum indicates that this parameter is noise tolerant.

FIG 4 is a plot of the correlation for C/I > 100 dB and FIG 5 is a plot of the correlation for C/I=6dB.

With reference to FIGs 4 and 5 it is apparent that the correlation plot will become more and more like a circle for worse C/I, and, consequently, the optimum slope will then of course become less critical.

20 The probability functions for the DC error (as percentage of the amplitude) estimated from a burst of 128 symbols for C/I>100dB are illustrated in FIG 6. The solid line illustrates the probability function without compensation and the dashed line illustrates the probability function with a compensation slope value of 2 (compensation factor).

FIG 7 shows probability functions as a result of the compensation according to the invention for different C/I: Solid line C/I>100dB, Dashed line C/I=20dB, Dash-dotted C/I=12dB and Dash double dotted C/I=6dB.

FIG 8 shows the compensated probability function for different SNR: Solid line SNR>100dB, Dashed line SNR=20dB, Dash-dotted SNR=12dB and Dash double dotted SNR=6dB.

The performance of the method according to the invention is reduced when an interfering signal (noise or

other GMSK-signal) is added to the wanted signal. This is not a big problem, because the performance will mainly be set by the fact that an interfering signal is present. For high SNR and C/I the homodyne radio receiver apparatus  
5 according to the invention suppresses the remaining limiting factor, which is the error in the DC-calculation.

The relationship between the error in the calculation of the DC-level and the performance degradation is progressive. This causes a substantial reduction of the  
10 number of bit errors even for a small improvement in the DC-level calculation, which is shown by the two graphs in FIG 6.

Consequently, by considering information characteristics of the received signal burst and use it in  
15 the DC-level estimation, the DC-level error can be considerably reduced for high C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio) signal conditions.

Even though, any interfering signal or distortion from the receiver filters reduces the performance, the  
20 resulting DC-level estimation according to the invention is still satisfying for most applications.

The optimum slope is flat, which makes it possible to implement the DC-level estimation with a fix number of the compensation factor, for example -2.0.

25 It has been shown that the difference between the number of samples with an amplitude value above/below a fix limit is strongly correlated with the DC-error, and therefore this is used in a second embodiment of the invention.

30 With reference to FIG 1B, a signal burst containing a number of symbols, including a carrier signal modulated by a modulating signal, is received by an antenna 11 and is filtered by a bandpass filter 12. An amplifier 13 amplifies the filtered signal generated by the filter 12. Further,  
35 the amplified signal burst is downconverted to complex base

band signals I (in-phase) and Q (quadrature) by a conventional quadrature down-converter 14. The output I, Q from the down-converter 14 is preferably filtered and amplified by additional filters and amplifiers before the output is  
5 sampled and converted to a digital signal by an analog-to-digital converter ADC 15,15'. The digital signal may be filtered in a digital filter, and the digital data symbols or samples contained in the signal are supplied to a digital memory 16 for later retrieval.

10 The output from the ADC 15,15' is fed to a DC compensation device 17, which determines a DC-level estimate of the received signal and subtracts the determined DC-level from the signal burst before it is demodulated. In order to determine the DC-level estimate  
15 the DC compensation device is adapted to process the received signal burst in a plurality of steps according the second embodiment of the invention. The output of the ADC 15,15' is fed to an average calculator 18,18', which estimates the average DC-level of a number of samples,  
20 subtracts the estimated DC level from each sample before they are fed to the next step. Additionally, the average calculator 18,18' determines the peak value of the signal by identifying the maximal sample value and subtracting the estimated average DC-level from the maximal sample value.  
25 The peak value is supplied to the next step of the signal path together with the estimated average DC-level.

The next step in the signal path is a signed sum calculator 19,19'. The digital data symbols or samples of the received signal burst stored in the digital memory 16  
30 are read by the signed sum calculator 19,19', which standardizes the symbols with reference to the estimated average DC-level and the peak value before a signed sum of the samples are calculated and weighted by a compensation factor, described later.

The output of the signed sum calculator 19,19' is supplied to a correction and calculator block 20,20', in which an improved DC-level estimate is calculated by subtracting the weighted calculated signed sum from the estimated average DC-level. Finally, the improved DC-level estimate is subtracted from each sample read from the memory 16.

Consequently, the output of the correction and calculator block 20,20' at the end of the signal path will finally provide a stream of digital data symbols, that were contained in and carried by the analog signal initially received at the antenna 1, but compensated by the DC-level, resulting from the estimation as described.

Thus, in this embodiment of the invention, the DC-level is estimated according to the following expression (5) for the compensation:

$$DC_{estimate2} = DC_{average} - B \cdot DC_{error2} \quad (5), \text{ wherein}$$

$$DC_{average} = \frac{1}{N} \sum_{i=1}^N S(i) \quad (2), \text{ and}$$

$$DC_{error2} = \sum_M y \quad (6)$$

Thus, the estimated DC-level,  $DC_{estimate2}$ , is the average DC-level,  $DC_{average}$ , calculated over  $N$  symbols  $S(i)$  compensated by a DC-error,  $DC_{error2}$ , which is multiplied by a compensation factor  $B$ . The DC-error is estimated by calculating the signed sum of the signal, calculated over  $M$  symbols  $S(j)$ , wherein  $y = S(j) - DC_{average}$ .

A plot of the correlation coefficient versus the counter limit, the percentage of the amplitude, is shown in FIG 9. An optimal correlation is achieved if only samples ( $S(j)$ ) above/below 30-50% and preferably 40% of the amplitude is used for the calculations of the difference of the number of positive and negative samples. The error in

the DC-level estimate makes the samples close to the DC-level more uncertain and therefore a higher limit is preferable. However, a higher limit decreases the number of samples available for the calculations. As mentioned above, the flatness of the optimum indicates that the compensation factor is noise tolerant.

An optimal compensation factor is determined for different C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio), assuming white noise.

FIG 10 shows the DC estimate error, as a percentage of the amplitude, as a function of the difference between the number of negative and positive samples, and FIG 11 shows -5% to +5% error estimate as a function of the compensation slope.

It is apparent from the graph in FIG 10 that a compensation factor of 0.0055-0.0065 and preferably 0.006 is the optimal relationship between the DC-error and the signed sum. Thus, the following expression is an example of a compensation expression used by the DC compensation device 4 for determining a DC-level estimate if only samples ( $y$  in the expression (6)) above/below 40% of the amplitude is used for the calculations.

$$DC_{estimate2} = DC_{average} - 0.006 \cdot DC_{error2} \quad (5), \text{ wherein}$$

The flatness of the optimum indicates that this parameter also is noise tolerant.

The probability functions for the DC error (as percentage of the amplitude) estimated from a burst of 128 symbols for C/I > 100dB are illustrated in FIG 12. The solid line illustrates the probability function without compensation and the dashed line illustrates the probability function with a compensation slope value of 0.006.

Consequently, by considering information characteristics of the received signal burst and using only

samples above/below a certain percentage of the amplitude is used for the DC-level estimation, the DC-level error can be considerably reduced for high C/I (carrier-to-interference ratio) and SNR (signal-to-noise ratio) signal  
5 conditions.

Although the invention has been described by way of a specific embodiments thereof it should be apparent that the present invention provides an improved DC estimate method and a homodyne radio receiver apparatus that fully  
10 satisfies the aims and advantages set forth above, and alternatives, modifications and variations are apparent to those skilled in the art.

The DC-compensation device is a digital signal-processing device preferably implemented as a hard-wired  
15 logic circuitry for the speed performance. However, the DC-compensation device can be implemented as an ASIC integrated digital signal processor in an alternative embodiment of the invention.

Further systems like EDGE and AMR have some coding  
20 scheme that relays one good signal condition. One single bit error will force a retransmission of a large block and will therefore reduce the data throughput.



## CLAIMS

1. A homodyne radio receiver apparatus, comprising a homodyne radio receiver device (1,2,3,4,5,5') for receiving radio frequency signal bursts of a number of symbols and  
5 generating digital samples of at least a complex base band signal (I and Q) of each signal burst, and DC compensation means (7) operatively connected to said homodyne radio receiver device (1,2,3,4,5,5') for determining a DC-level estimate of said samples, wherein said DC compensation  
10 means (7) comprises average calculator means (8,8') for calculating an average DC-level of said samples,  
**characterized** in that said DC compensation means (7) further comprises signed square sum calculator means (9,9') for calculating a signed square sum of a plurality of said  
15 samples and weighting said square sum by a compensation factor (A), and correction means (10,10') for subtracting an output of said square sum calculator means (9,9') from an output of said average calculator means (8,8') for forming said DC-level estimate.

20

2. A homodyne radio receiver apparatus according to claim 1, **characterized** in that said compensation factor (A) is -1 to -3 and preferably -2.

25 3. A homodyne radio receiver apparatus, comprising a homodyne radio receiver device (11,12,13,14,15,15') for receiving radio frequency signal bursts containing a number of symbols and generating digital samples of at least a complex base band signal (I and Q) of each signal burst,  
30 and DC compensation means (17) operatively connected to said homodyne radio receiver device (11,12,13,14,15,15') for determining a DC-level estimate of said samples, wherein said DC compensation means (17) comprises average calculator means (18,18') for calculating an average DC-  
35 level of said samples, **characterized** in that said DC compensation means (7) further comprises signed sum

calculator means (19,19') for calculating a signed sum of a plurality of said samples and weighting said sum by a compensation factor, and correction means (20,20') for subtracting an output of said signed sum calculator means  
5 (19,19') from an output of said average calculator means (18,18') for forming said DC-level estimate.

4. A homodyne radio receiver apparatus according to claim 3, **characterized** in that said samples having an  
10 amplitude value of at least 40% of the amplitude of said modulating signal.

5. A homodyne radio receiver apparatus according to claim 4, **characterized** in that said compensation factor is  
15 0.0055 - 0.0065 and preferably 0.006.

6. A homodyne radio receiver apparatus according to any of the preceding claims, **characterized** in that said DC compensation means (7;17) is a digital signal processing  
20 device.

7. A homodyne radio receiver apparatus according to any of the preceding claims, **characterized** in that said homodyne radio receiver device comprises signal receiver  
25 means (1,2,3;11,12,13) operatively connected to a quadrature down-converter (4;14) for downconverting said signal burst to at least a complex base band signal (I and Q), and an analog-to-digital converter (5,5';15,15') for generating said samples.

8. A homodyne radio receiver apparatus according to any of the preceding claims, **characterized** in that said correction means (10,10';20,20') is adapted to subtract  
30 said DC-level estimate from each sample.

9. A signal processor for compensating a DC-level of a radio frequency signal bursts received in a homodyne radio receiver, comprising signal receiving means for receiving digital samples of at least a complex base band signal (I and Q) generated by said homodyne radio receiver, DC compensation means (7) for determining a DC-level estimate of said samples, average calculator means (8,8') for calculating an average DC-level of said samples, **characterized** by signed square sum calculator means (9,9') for calculating a signed square sum of a plurality of said samples and weighting said square sum by a compensation factor, and correction means (10,10') for subtracting an output of said square sum calculator means (9,9') from an output of said average calculator means (8,8') for forming said DC-level estimate.

10. A signal processor according to claim 9, **characterized** in that said compensation factor is -1 to -3 and preferably -2.

11. A signal processor for compensating a DC-level of a radio frequency signal bursts received in a homodyne radio receiver, comprising signal receiving means for receiving digital samples of at least a complex base band signal (I and Q) generated by said homodyne radio receiver, DC compensation means (17) for determining a DC-level estimate of said samples, average calculator means (18,18') for calculating an average DC-level of said samples, **characterized** by signed sum calculator means (19,19') for calculating a signed sum of a plurality of said samples and weighting said sum by a compensation factor, and correction means (20,20') for subtracting an output of said signed sum calculator means (19,19') from an output of said average calculator means (18,18') for forming said DC-level estimate.

12. A signal processor according to claim 11, **characterized** in that said samples having an amplitude value of at least 40% of the amplitude of said modulating signal.

5

13. A signal processor according to claim 12, **characterized** in that said compensation factor is 0.0055 - 0.0065 and preferably 0.006.

10

14. A signal processor according to any of the claims 9-13, **characterized** in that said homodyne radio receiver device comprises signal receiver means (1,2,3;11,12,13) operatively connected to a quadrature down-converter (4;14) for downconverting said signal burst to at least a complex base band signal (I and Q), and an analog-to-digital converter (5,5';15,15') for generating said samples.

15

15. A signal processor according to any of the claims 9-14, **characterized** in that said correction means (10,10';20,20') is adapted to subtract said DC-level estimate from each sample.

20

16. A method of DC-level estimation in a homodyne radio receiver apparatus, wherein a radio frequency signal burst containing a number of symbols is received in the apparatus, digital samples of at least a complex base band signal (I and Q) of each signal burst are generated, and an average DC-level estimate of said samples is determined, **characterized** by the further steps of:

25

30 determining a signed square sum of a plurality of said samples and weighting said square sum by a compensation factor, and subtracting said signed square sum from said average DC-level for forming said DC-level estimate.

35

17. A method according to claim 16, **characterized** in that said compensation factor is -1 to -3 and preferably -2.

5           18. A method of DC-level estimation in a homodyne radio receiver apparatus, wherein a radio frequency signal burst containing a number of symbols is received in the apparatus, digital samples of at least a complex base band signal (I and Q) of each signal burst are generated, and an  
10 average DC-level estimate of said samples is determined, **characterized** by the further steps of:

          determining a signed sum of a plurality of said samples and weighting said signed sum by a compensation factor, and subtracting said signed sum from said  
15 average DC-level for forming said DC-level estimate.

19. A method according to claim 18, **characterized** in that said compensation factor is 0.0055 - 0.0065 and preferably 0.006.

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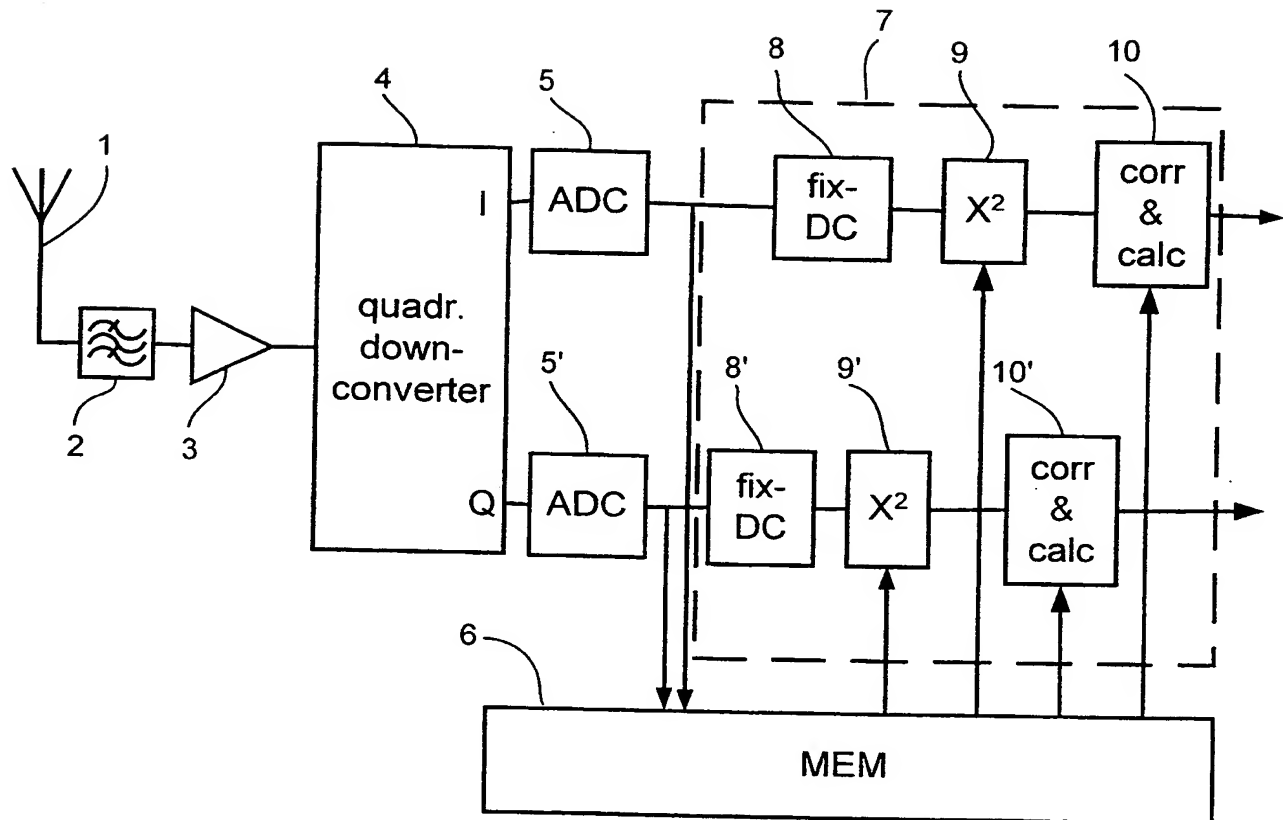


FIG. 1A

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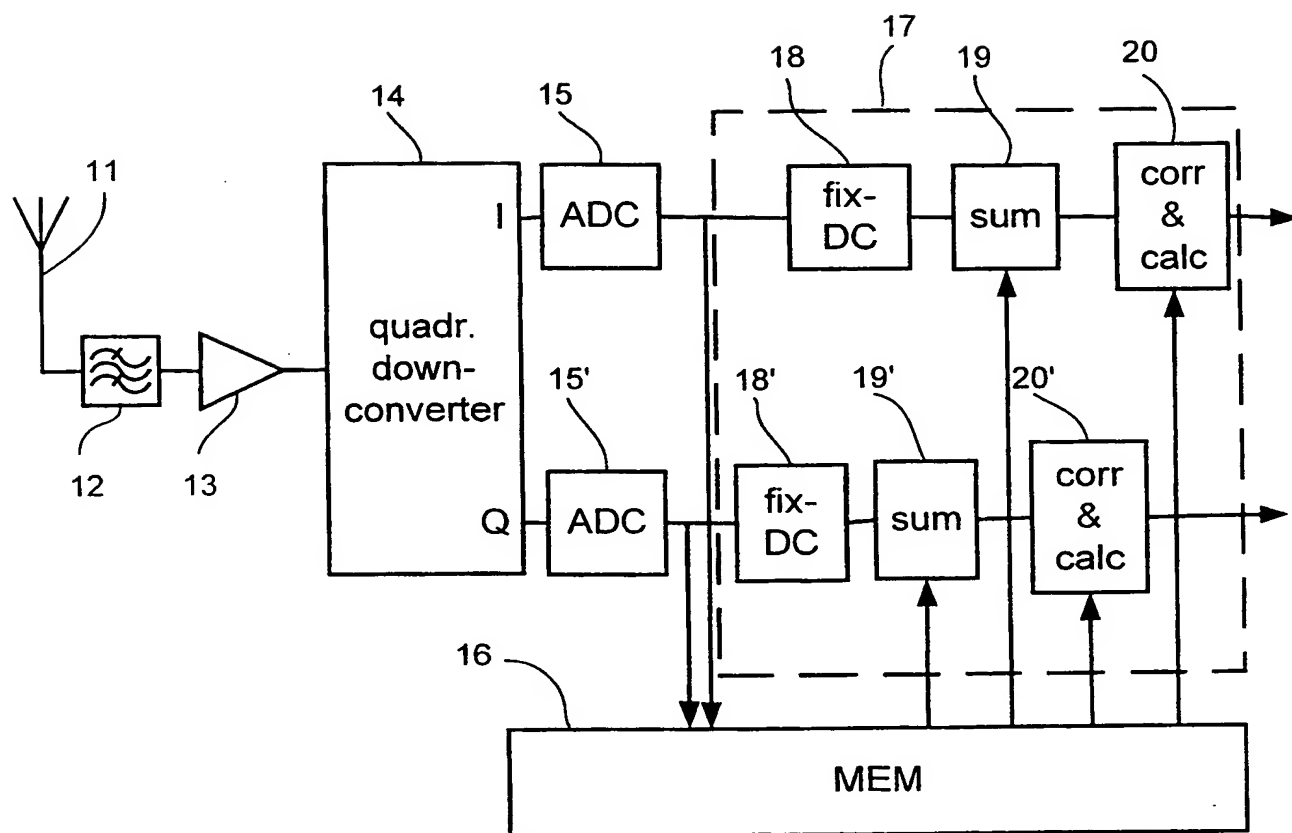
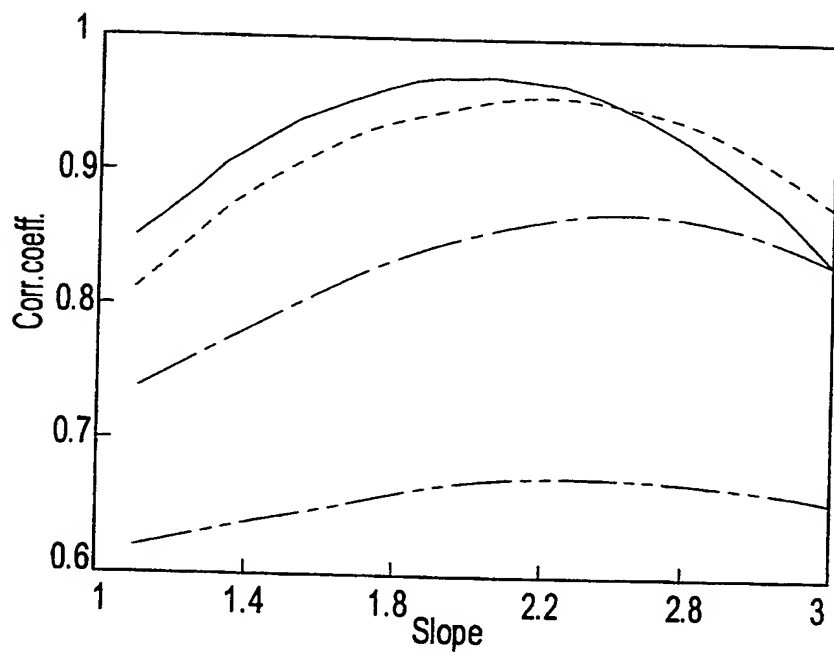
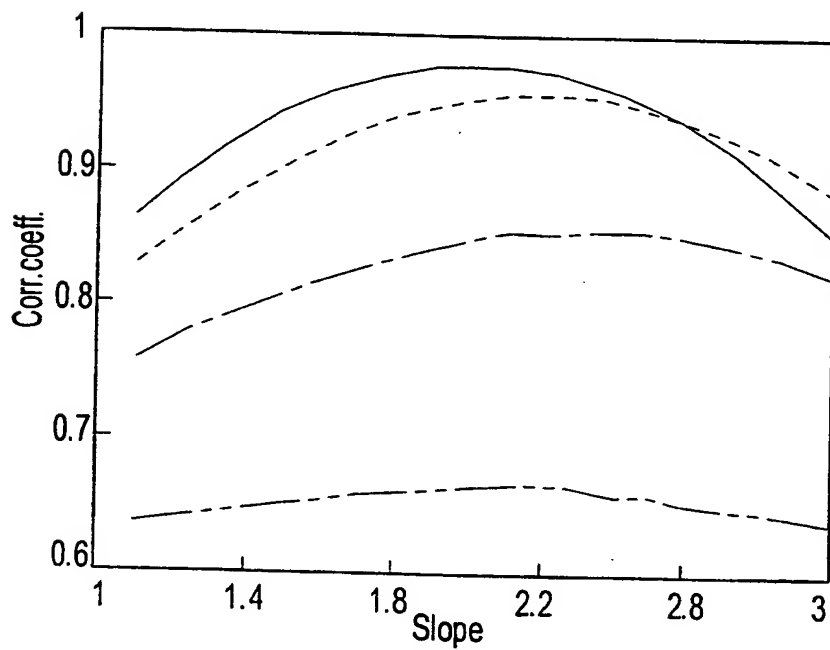


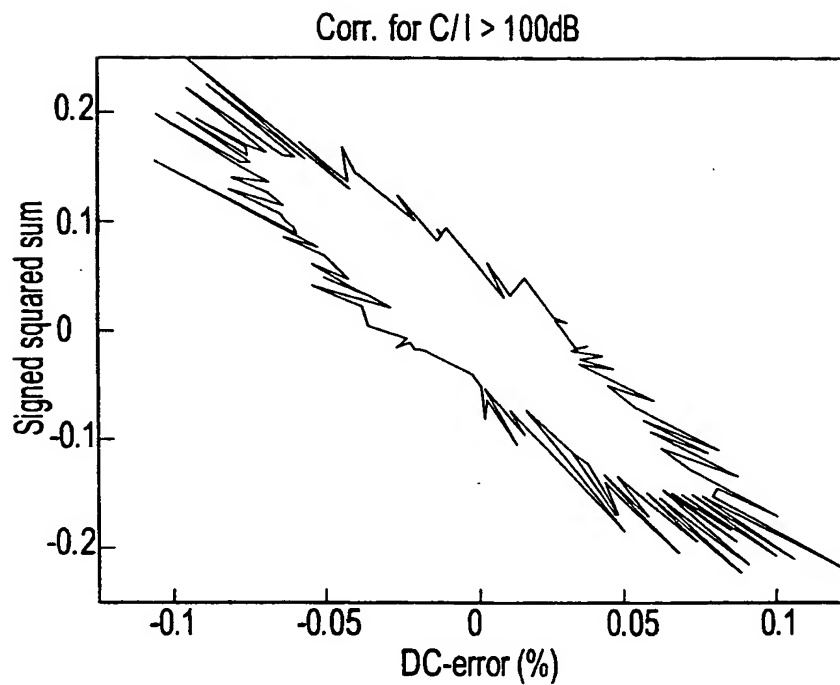
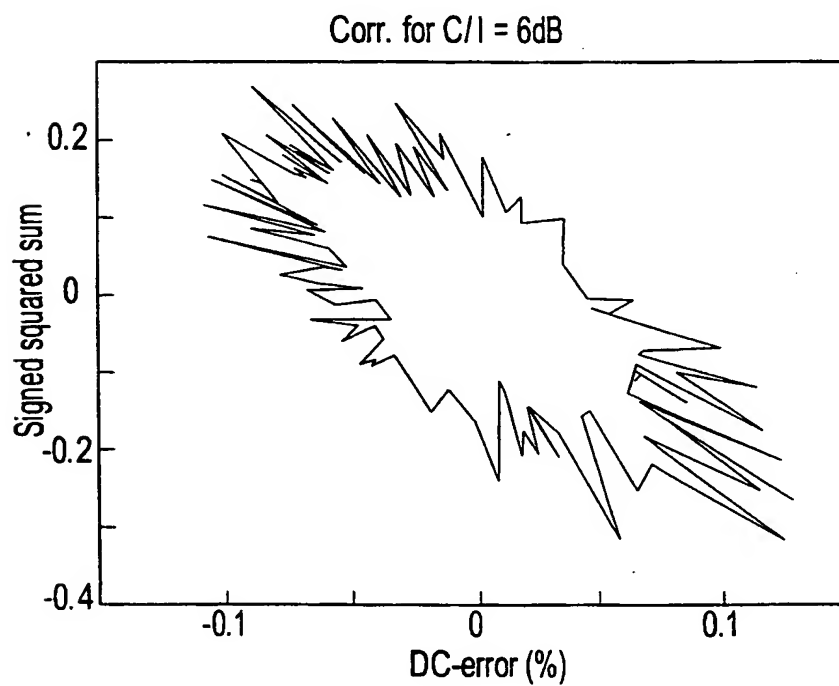
FIG. 1B

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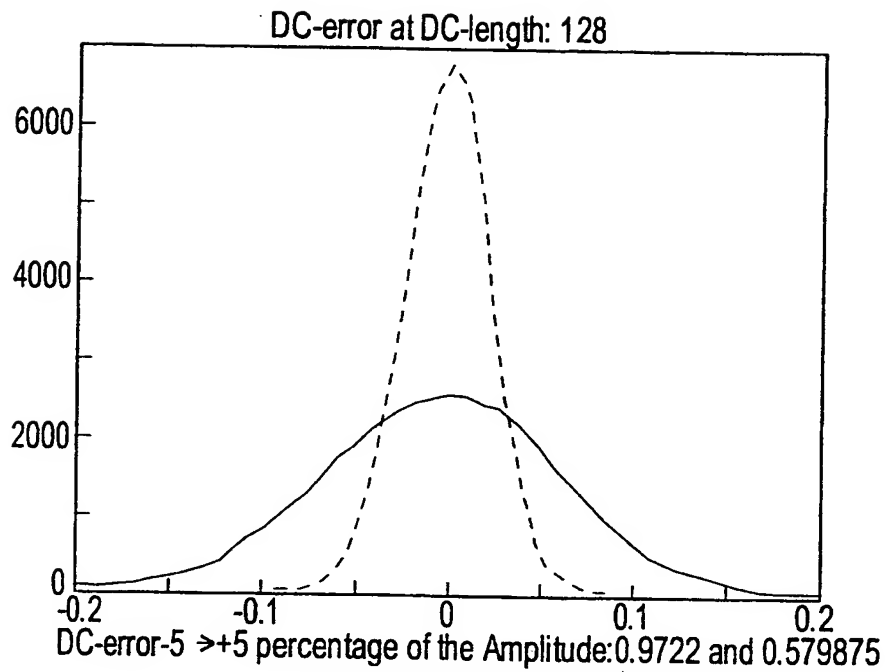
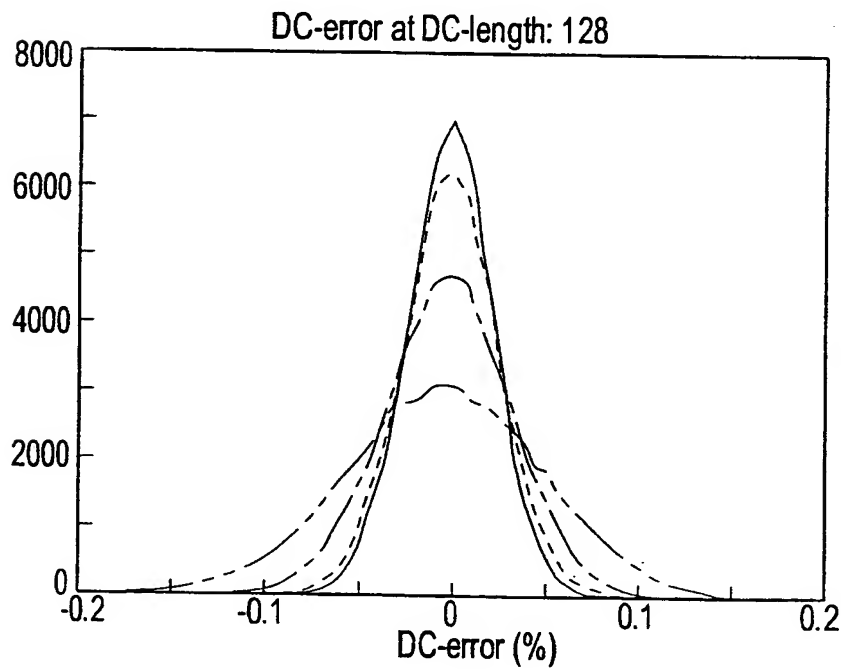
*Fig. 2**Fig. 3*



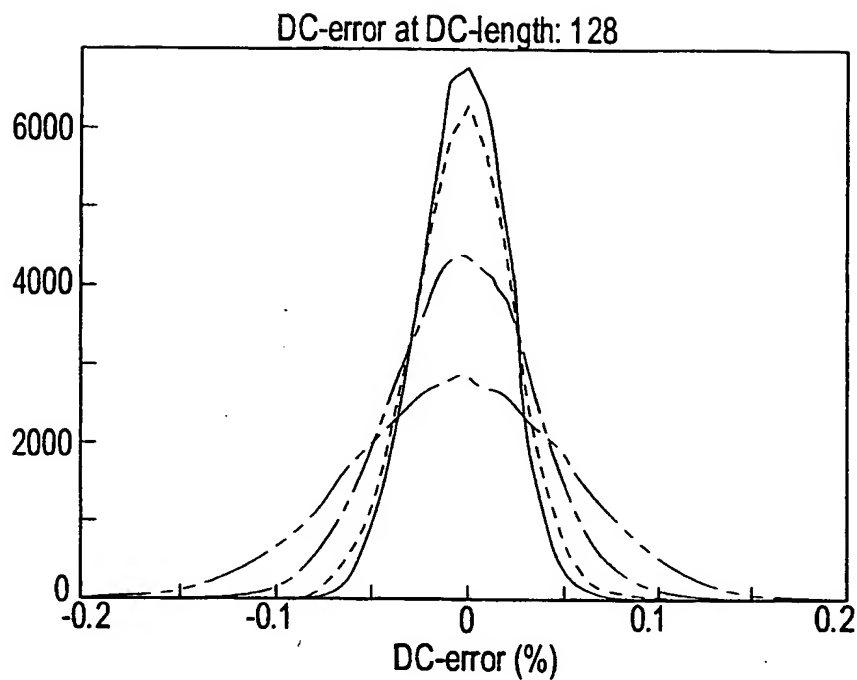
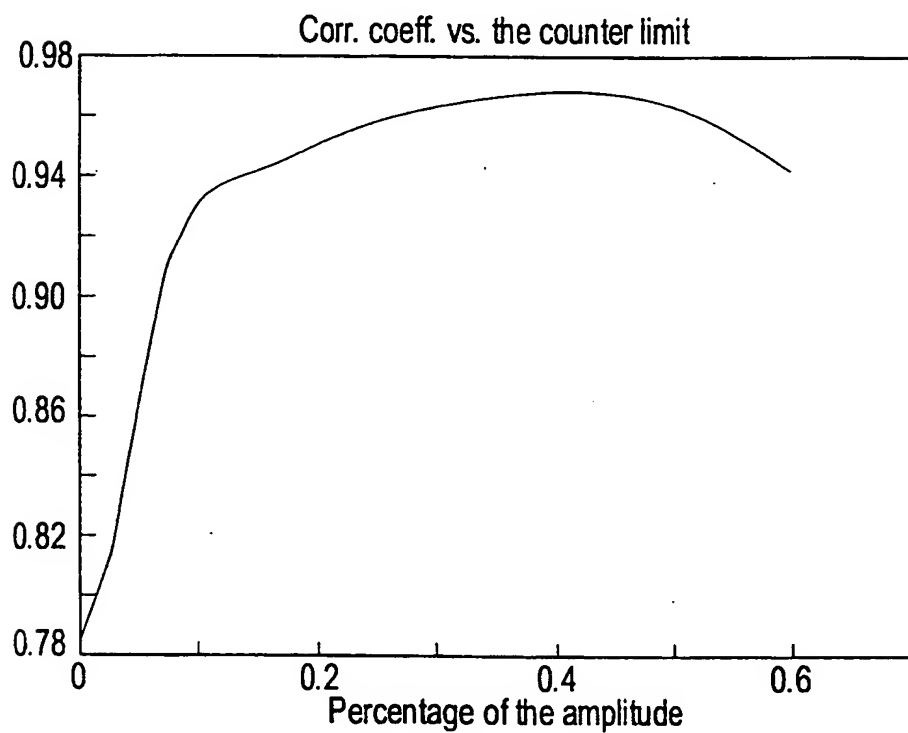
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*Fig. 4**Fig. 5*

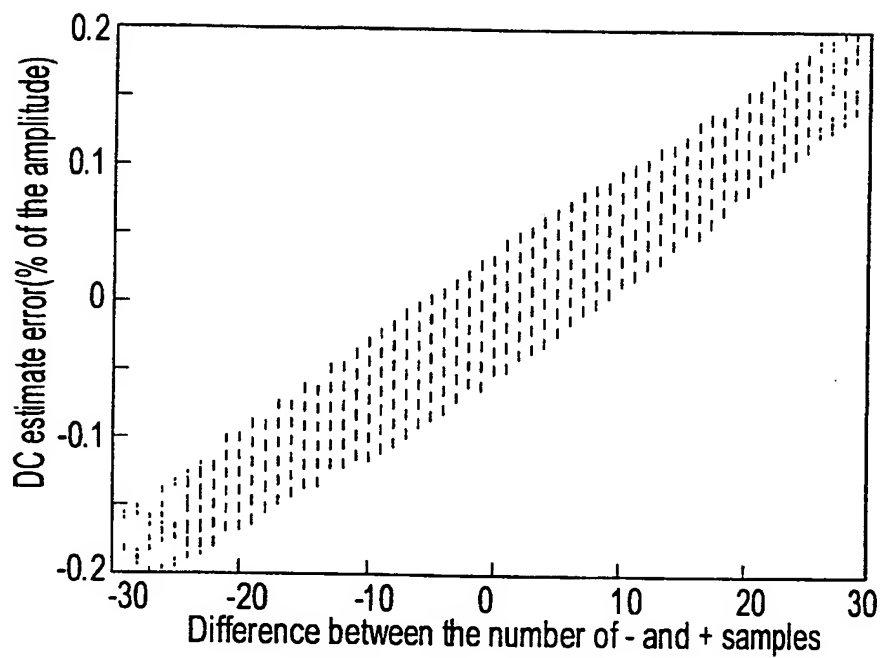
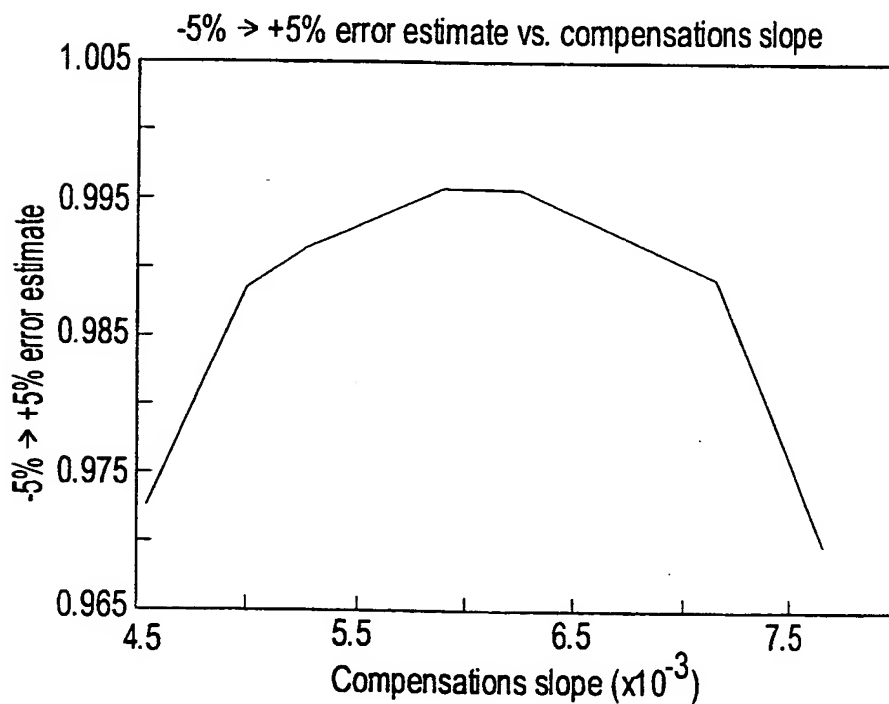
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*Fig. 6**Fig. 7*

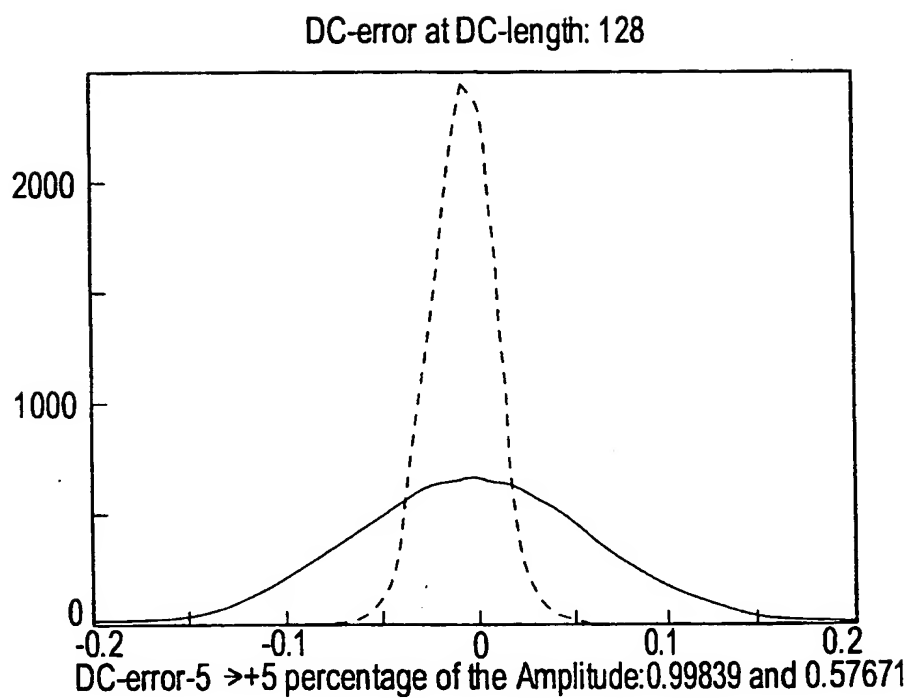
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*Fig. 8**Fig. 9*

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*Fig. 10**Fig. 11*

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*Fig. 12*



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(71) Applicant: **TELEFONAKTIEBOLAGET LM ERICSSON** [SE/SE]; S-126 25 Stockholm (SE).

(72) Inventors: **JAKOBSSON, Jan, Peter**; Trollebergsvägen 89 B, S-227 31 Lund (SE). **STENSTRÖM, Sven, Erik**, Niklas; Fågelsångsgatan 27, S-252 20 Helsingborg (SE).

(74) Agents: **STRÖM, Tore et al.**; Ström & Gulliksson AB, P.O. Box 4188, S-203 13 Malmö (SE).

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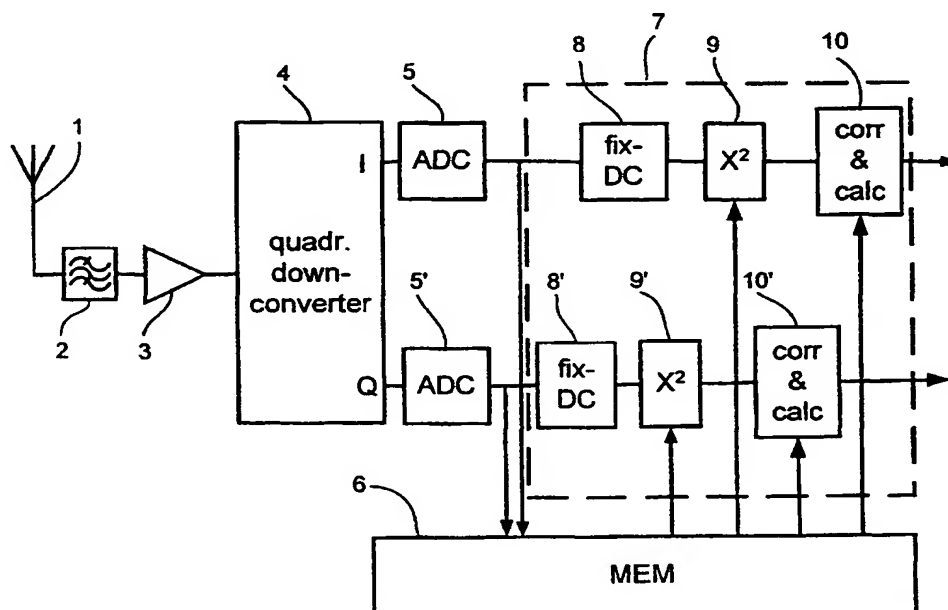
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7 December 2000

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A HOMODYNE RADIO RECEIVER



(57) Abstract: A homodyne radio receiver apparatus receives radio frequency signal bursts containing a number of symbols and generates digital samples of at least a complex base band signal (I and Q) of each signal bursts. A DC compensator comprises an average calculator (8, 8'), which determines an average DC-level of said samples, and a signed square sum calculator (9, 9'), which calculates a signed square sum of a plurality of said samples and weights the square sum by a compensation factor. Correction means (10, 10') subtracts the square sum from an output of said average calculator means for forming the DC-level estimate.

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/SE 00/00147

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 1/30

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4873702 A (RAN-FUN CHIU), 10 October 1989 (10.10.89), column 2, line 27 - line 43 --	1-19
A	US 5697085 A (WINFRID BIRTH ET AL), 9 December 1997 (09.12.97) --	1-19
A	EP 0611057 A2 (NOKIA MOBILE PHONES LTD.), 17 August 1994 (17.08.94) -- -----	1-19

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Information on patent family members

International application No.

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